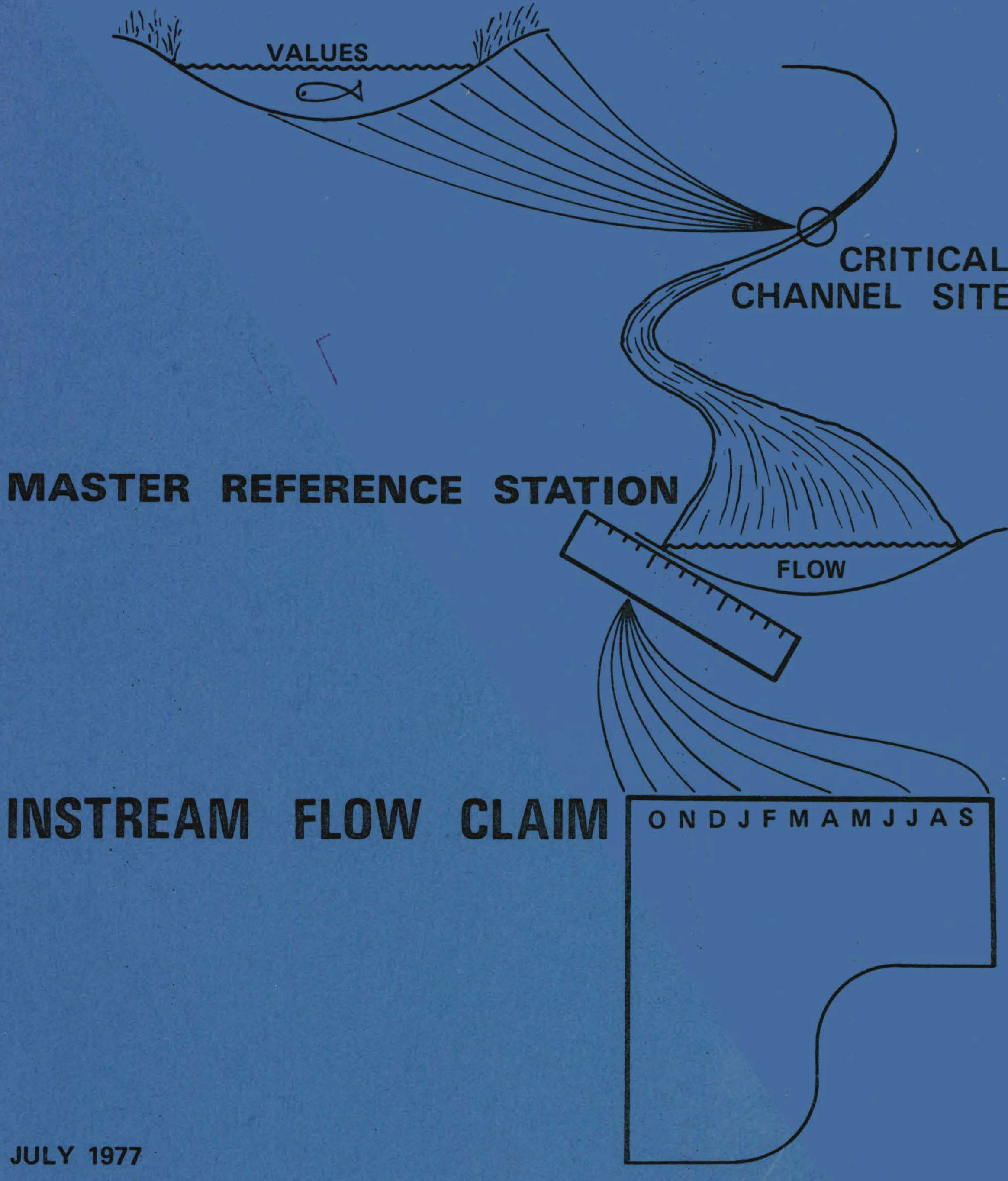
Procedural Guidelines for Instream Flow Determinations

U. S. FOREST SERVICE
REGION 4



JULY 1977

PROCEDURAL GUIDELINE

FOR

INSTREAM FLOW DETERMINATIONS

U. S. Forest Service
Region 4

An Interdisciplinary Approach
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PURPOSE

This document provides guidelines for evaluating instream flow requirements on National Forest lands in the Intermountain Region. The guide is not intended to be all inclusive; rather, it provides a framework where specialists can find direction and still have the freedom to use the best available technology in developing their inputs.

AUTHORITY AND POLICY

The United States claims a right to maintain continuous, uninterrupted flows of water that are sufficient in quantity and quality to meet the purposes for which National Forests were established. This principle was affirmed by the Supreme Court in 1963 (Arizona vs. California).

Basic authority comes from the Organic Administration Act of June 4, 1897, which states, "no national forest shall be established, except to improve and protect the forest within the boundaries, or for the purpose of securing favorable water flows, and to furnish a continuous supply of timber for use and necessities of citizens of the United States."

The Multiple Use-Sustained Yield Act of June 12, 1960, states, "that it is the policy of the Congress that the national forests are established and shall be administered for outdoor recreation, range, timber, watershed, and wildlife and fish purposes."

Additional direction is given in the 2500 section of the Forest Service Manual.

DEFINITION OF INSTREAM FLOWS

Instream flows are quantities of water needed in a channel system during various seasons to maintain favorable conditions of water flows that meet specific purposes for which National Forests were established including maintenance and protection of:

1. A viable aquatic ecosystem which contains fisheries, riverine wildlife, aquatic organisms, and riparian vegetation.

2. A stable channel and bank system.

3. Acceptable water quality conditions.

4. Suitable flows for navigation.

5. Public recreational and esthetic benefits associated with favorable water flow conditions.

Instream flow boundary conditions are identified in Appendix IV.

GOALS

Two major goals currently provide direction in the determination of instream flow claims. These are:

1. To identify instream flow needs at the National Forest level for documentation in the land management planning process.

   Comprehensive land management plans currently being prepared provide a means whereby a planning team and decisionmakers can analyze and document the amount, location, timing, and availability of water needed to meet management objectives. Because this information is taken before the public for their evaluation, the soundness of the decisions can be tested and modifications made if needed.

2. To identify instream flow needs throughout the Region for water adjudication proceedings that include claims of the United States.

   Although many States have been notified of National Forest water uses and foreseeable needs for consumptive purposes, instream flow requirements have not always been identified. This needs to be corrected since the United States can be joined as a defendant in State water right proceedings involving Federal reserved rights.

PROBLEM ANALYSIS STEPS

In pursuing both goals, it becomes essential to identify the purposes for which instream flows are needed, where instream flows are needed, and the quantities of water involved. The following steps should be followed where appropriate:

1. Establish Forest priorities for evaluating instream flow needs.
2. Prepare appropriate maps showing land ownership patterns including reserved lands, acquired lands, and alienated lands where instream needs are being evaluated. Reservation dates should be shown for all reserved lands.
3. Identify points where diversions have been or will be made in the foreseeable future that involve reserved and/or appropriative rights of the United States and appropriative rights of others.
4. Establish interdisciplinary study team with appropriate specialists.
5. Determine season of use and quantities of water being diverted.
6. Determine instream flow uses by season.
7. Identify data base available for analysis of streamflow and flow related values.

8. Determine the range in and seasonal distribution of streamflow by making appropriate measurements or by making estimates based on available records.

9. Identify critical channel sites and establish master reference stations.

10. Develop criteria for evaluating instream flow requirements.

11. Select methodologies for evaluating streamflow and flow related stream qualities.

12. Evaluate seasonal flow alternatives considering water availability and the social and economic values associated with required instream flows.

13. Develop a schedule of flows required to meet National Forest needs at each reference station.

14. Prepare instream flow inventory Form R4-2500-23a for submission to the Regional Office (Appendix I).

INSTREAM FLOW METHODOLOGY

Establish Forest Priorities (Step 1)

There should be a Forest priority listing for drainage basins or stream reaches to be evaluated. These priorities should be based on proposed adjudication schedules and on water impoundment and/or diversion proposals. Other considerations include the value of fisheries, recreation, esthetics, navigation, and production of high quality waters.

Priority areas can be tied to land management planning, adjudication areas, or any other appropriate unit which has significance in water planning and management.

Develop Maps (Step 2)

Maps with a scale of 1/2" = 1 mile are generally appropriate for identifying land ownership patterns that have an influence on the alternatives available for controlling instream needs. These maps are used to show reserved lands, acquired lands, and alienated lands.

Diversions and uses on alienated lands within National Forest boundaries may reduce flows to levels that are incompatible with the stated Forest goals. These problems may or may not be controllable. In either case, this information should be included in the planning process. Also, the location of acquired lands should be identified because reserved rights cannot be applied to waters flowing over these lands.

Reservation dates on National Forest lands are used in establishing seniority of claims in adjudications. Because several dates are included on most Forests, careful attention should be given to this matter.

Identification of Existing and Future Diversions (Step 3)

Inventories on water uses and needs have been completed on most National Forests within the Region. These inventories provide information on the timing of water use, the amount of water being used, the purposes of such use, and the locations of diversion and use. However, a complete record of the water rights of others which are valid against the United States is usually not available on the Forest inventories.

Establish Interdisciplinary Team (Step 4)

An interdisciplinary team approach is required when quantifying instream flows. Selected team members should be involved in the development of a working plan, in the selection of key stream reaches for study, and in data collection and analysis. Hydrologists, recreation specialists, fisheries biologists, wildlife biologists, economists, forest-range specialists, and others may be involved.

The responsible line officer should provide a briefing to the team regarding:

1. General scope of problem including the purpose and goal of instream flow quantification.

2. Administrative, financial, legal, physical, biological, and time constraints.

3. Reporting needs and problem format.

4. Responsibilities of task members.

Typical task assignments for team members:

Hydrologist

1. Develops estimates of flow based on available information (USGS). Flow duration curves or low-flow recurrence interval curves are examples.

2. Develops legal history of water users on drainages, showing order of rights, volumes of water involved, and timing of respective water uses.

3. Examines stream channel hydraulics with special regard for channel problems that may develop with flow diversion or alterations. When

desired, locates critical channel sites to determine flows needed to minimize sediment deposition or channel scour and streambank erosion.

4. Participates in location and calibration of Master Reference Stations (MRS).

5. Assists all disciplines in relating flows at critical channel sites to flows at MRS. Coordinates and explains use.

Fisheries Biologist

1. Reviews available information in regards to the fisheries and aquatic fauna of the stream in question.

2. Designs field study for aquatic habitat analysis.

3. Selects and evaluates the critical fisheries sites and relates data from habitat sampling to master reference stations.

4. Makes fisheries recommendations based on changes in habitat which reflect changes in production with incremental changes in flow.

Recreation and Landscape Architect

1. Reviews and locates key recreation use areas and areas of critical scenic beauty.

2. Develops evaluation criteria and relates the various quality values to Master Reference Stations.

3. Develops pictorial exhibits of scenic qualities related to stage or flow values through the season of use.

4. Works with the hydrologist and other team members on any navigable reaches.

5. Quantifies changes in visual quality and recreational values with changes in flow.

All Team Members

1. Participate in an analysis leading to determination of needed instream flows for set purposes and goals defined initially.

2. Participate with other members of team in preparation of graphs and tables needed in adjudication hearings.

3. Participate with other team members to aid line officer in decision-making.

4. Maintain a brief record of public and out-agency involvement.

   Coordination among team members is essential from beginning to end of the study in order to keep the study concise and within the scope of the objectives.

Identify Season of Use and Quantity of Water Being Diverted (Step 5)

It is essential to identify the amount of water being diverted during different seasons so that conflicts with instream use will be apparent. This should be done by stream reach.

Identify Type and Season of Instream Use (Step 6)

It is important to document instream uses by reach so the information can be correlated with the quantity of water being diverted during various seasons. A display such as figure 1 can be developed which compares the season of use for both diversions and instream values. This aids in identifying major conflicts between specific instream and diverted uses.

Identify Streamflow Data Base (Step 7)

The development of a hydrologic data base should always begin with a search for available data. Some data sources are:

1. U.S. Geological Survey streamflow records for both existing and discontinued gages. Look at all gages which may be in a similar hydrologic or physiographic region.

2. U.S. Geological Survey water quality records which often contain an instantaneous measure of discharge.

3. In-Service and Out-Service land management documents.

4. Department of Commerce "Weather Bureau" documents.

5. U.S. Geological Survey unpublished records.

6. U.S. Geological Survey flood prediction techniques. These often contain information relating drainage area, precipitation, and elevation to streamflow.

7. Forest Service administrative studies including Barometer Watersheds.

8. Research studies either by universities, Forest Service, and other State and Federal agencies.

9. Municipal water system records.

Figure 1. Watershed 029 - Sweetwater Reach 3

INFORMATION BASE	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
AVERAGE DISCHARGE (cfs)	5	5	5	5	5	10	20	50	30	20	10	8
DIVERSIONS FOR USE (cfs)												
1. Brimful Irrigation Co.										2		
2. Dry Lake Reservoir Storage									5			
INSTREAM USES (cfs)												
1. Floating Navigation								15				
2. Fisheries						4						
3. Recreational Uses										5		
4. Riparian Vegetation										1		
5. Channel Flushing								25				
INSTREAM NEED (cfs)	4	4	4	4	4	4	4	25	15	5	5	5
FLOW AVAILABLE AFTER DIVERSION (cfs)	5	5	5	5	5	10	20	50	25 | 23	18	8	6

10. Qualitative description of flow obtained from local residents.

11. Irrigation company records.

Determine Seasonal Distribution of Streamflow (Step 8)

Understanding the seasonal variation of streamflow is essential in the development of reasonable instream flow claims.

The most basic evaluation of streamflow distribution is average monthly flow. More detailed information may be obtained by constructing monthly flow duration curves using average monthly values. The most intense level of displaying seasonal distributions is to construct monthly flow-duration curves using mean daily flows. The more valuable the use of the stream, the more detailed should be the analysis of seasonal variation.

Under normal circumstances, the above data are not available at the location of interest. Consequently, these flows should be correlated with drainage area to extrapolate the data to any reference station.

Identify Critical Channel Sites and Establish Master Reference Stations (Step 9)

A critical channel site is a location in a stream reach which will suffer the most impact from reductions in flow. If the needs of the most limiting site are met, then in proportion, the remainder of the stream reach needs are satisfied until the next diversion.

In general, where flow is increasing within a stream reach, the most critical channel site is the first riffle-pool complex immediately downstream from the diversion. In reaches where flow losses are occurring, the most critical site is likely to lie near the end of the reach. Where both gains and losses are occurring, there may be several critical sites within a stream reach.

Because the critical channel site may only be critical for a specific use, i.e., fisheries, boating, water quality, etc., it may be necessary to identify different critical channel sites for different stream uses. Instream flows must then be adequate to meet as many of the needs as possible.

The master reference station is a staff gage where a stage-flow (discharge) relationship is or can be developed. Generally, there will be one reference station associated with each reach having one or more critical sites. It is the key unifying element which enables us to interrelate the technical knowledge from the various disciplines and present a unified claim for each stream reach or group of reaches.

It provides a point for administering our claims and rights to ensure that the values are being met.

Master reference stations should be strategically located and limited to the number needed to characterize flow claims. Maximum use should be made of existing and discontinued USGS or other stream gaging sites. These will need to be supplemented as necessary considering stream reach characteristics, critical channel sites, major tributary locations, return flow zones, points of diversion, accessibility, and sensitivity of stage-discharge relationships.

To obtain maximum utility from the master reference station concept, staff gages should be located early in the study process so that all disciplines can reference their observations at critical channel sites to the staff gage reading at the master reference site.

An example of how a master reference station can be established is included in Appendix II.

Develop Criteria for Evaluating Alternatives (Step 10)

The criteria provide the framework to test the viability of various alternatives. This is a line officer's job with the assistance of his staff or I.D. Team.

Criteria for evaluating alternatives are treated in two categories: mandatory and desirable. Some mandatory criteria follow:

1. Claims must be reasonable.

2. Claims must recognize rights of senior diverters in full.

3. Claims must be for identified National Forest purposes.

4. Claims must be quantified by amount and season.

5. Claims must be referenced to a reference station.

Only alternatives which meet all of the above criteria or others added by Forest line officers need to be considered further.

The following are examples of desirable criteria to use in selecting the claimed flow from remaining viable alternatives.

1. Claim minimizes losses to junior diverters.

2. Claim maximizes social good to the public in the long run.

3. Claim minimizes economic losses to any segment of society.

4. Claim has strong public support.

5. Claim maximizes multiple use benefits.

Screening alternatives in this two-phase process helps in quickly isolating the most desirable flow regime to claim for a specific section of stream represented by a master reference station.

Methodologies for Evaluating Stream Qualities (Step 11)

Several methodology components are presented. If all are not needed or if better methods are available, substitutions or deletions are appropriate.

Hydrologic Component

The hydrology component or flow characteristic may be the limiting factor and control all other stream qualities.

Information should be obtained on the quantity of water present in selected stream reaches. The information can then be related to the timing and sequence of life cycles of fish and other aquatic organisms, to wildlife habitat needs, to the type and location of recreational uses, and to the esthetic considerations involved. As a minimum, hydrologic information provides a measure of reasonableness to our claims; as a maximum it provides a correlation between streamflow, stream qualities, and drainage area.

Records Analysis

1. Assemble pertinent data identified in Step 7.

2. Analyze data.

The quantity of data available will determine to a large extent what analyses and correlations can be made. Whatever the case might be, the objective is similar: To obtain baseline information on streamflow characteristics with an evaluation of seasonal and yearly variation.

The first step towards analysis of existing data is to determine and display the natural variations of streamflow. It is likely that daily flows will be larger in a wet year than in a dry year. But the question is, how much larger? If an instream flow claim is to be reasonable, we must be certain that it falls within the natural range of flows at a given reference station.

The most basic data summaries needed are average monthly flows. This provides a rough estimation of the seasonal distribution of flows. If

records are available from several gages with different drainage areas, it may be possible to calculate a regression line showing how average monthly flow varies with drainage area. The value of such a regression is obvious: We can now extrapolate the seasonal variation of flow to any reference station or any critical channel site in the area of interest having a similar hydrologic response.

A more sophisticated approach to describe seasonal flow variation is with a flow-duration curve for each month. Flow-duration is nothing more than a histogram or a grouping of average daily flow values during a month and determining the percent of days in each group. Because this implies a lot of data to be manipulated, it is best done by a computer. The U.S. Geological Survey has a computer system called WATSTORE which calculates almost any flow variable if the data are USGS data and stored in their computer files.

If daily averages of flow are not available, then the flow duration can be done with mean monthly flow values. Figure 2 shows a typical flow-duration curve using daily values for a given month.

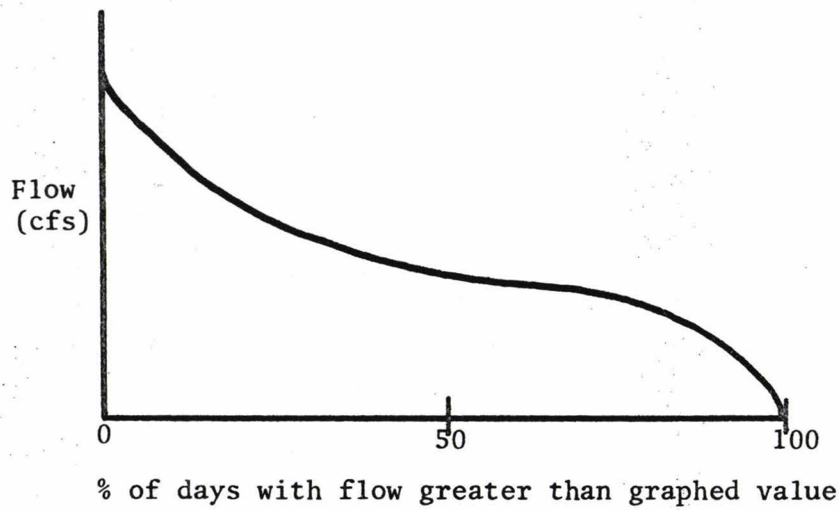


Figure 2. Flow duration curve.

Figure 2 should be interpreted as follows: For any point on the curve, the vertical axis shows the flow and the horizontal axis gives the percent of days with flow greater than that value.

Again, if several gages are available, it may be possible to develop a regression equation showing how the monthly flow duration curve varies with drainage area. Here lies the maximum value of the hydrologic data analysis. With such a relationship, the detailed variation of flows can be extrapolated to any reach or any reference point.

Figure 3 shows a flow-duration vs. drainage area plot for a given month. If this were the month of October, the curve indicates that for a drainage of 30-square miles, 9 days out of 10, the mean flow will be greater than 9 cfs, and 5 days out of 10, the flow will be greater than 20 cfs.

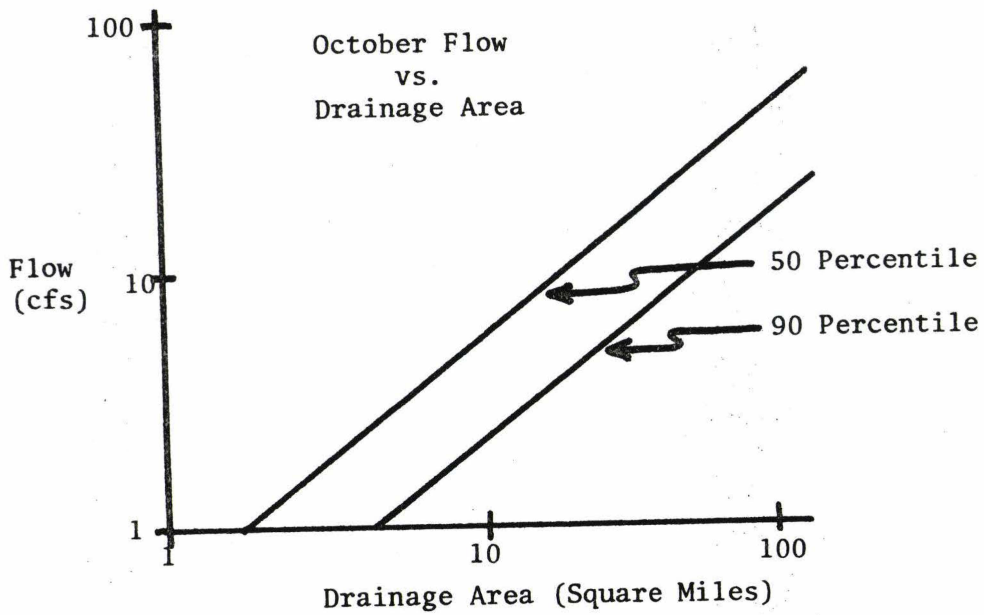


Figure 3. Flow-duration vs. drainage area.

Synthetic Data Creation

Because many basins do not have an adequate network of gaging stations, it may be necessary to use mathematical models to determine seasonal variation of streamflow. One example is described by Orsborn, et al., 1973. They show a method to determine mean monthly flows using drainage area and stream length.

Field Flow Measurement

A regional analysis of data and a synthetic estimation of flow variations do not explain all flow variations that occur. For

example, springs, ground water inflow, and elevation extremes may be such that the regression equations of flow vs. area do not hold. Consequently, when time permits, a suitable system must be established for relating short-term field measurements to long-term records on similar drainage basins to provide a means for evaluating seasonal and yearly variations.

(1) Flow Measurement Locations

Flow measurements are made at the master reference stations and at critical channel sites. These stations and sites should be located within 4th order watersheds as identified by the Water Resource Council. Stream reaches should be plotted on appropriate maps and identification numbers assigned in a logical order within these watersheds.

The location of a master reference station selected for evaluating streamflow depends on stream characteristics, major tributary locations, return flow zones, points of diversion and the nature of the study involved. Access also plays a key role in selecting locations. Suitable locations for evaluating streamflow might be above and/or below diversions, above and/or below major tributaries, or near bridge crossings. Flow measurements at National Forest boundaries may also be appropriate.

(2) Observation Frequency

The measurement schedule will depend on the study objectives, the data needs, and on the seasonal fluctuation patterns. In any case, measurements should be taken often enough to quantify the average monthly flow as well as the resource maintenance flow required to meet the instream needs.

(3) Measurement Procedures

Measurement procedures should be as simple and reliable as possible. It is desirable to establish staff gages or other visually observable devices at key reference stations. These devices should be calibrated with flow so they can be used in the enforcement of instream flow requirement. Also, they are important to the interdisciplinary team members who need to relate to a known flow when evaluating impacts of changes in water management.

(4) Correlation with Available Data

Because of the errors involved with extrapolating broad level data to specific stream reaches, all field data collected

should be used in the refinement of flow versus area regression plots. Adding more gages and expecting to wait several years for a data base is not practical. Consequently, flows from a permanent gage, preferably with several years of data, should be correlated with several individual flow measurements taken at a sample station. This procedure compares the instantaneous measurement with the mean daily flow value at the established gage. If a significant regression line can be fit to the data, then 8 or 10 measurements are converted to several years of data which adds one more point on the flow vs. area regression plots. The regression is thus improved by adding real data from the area of interest.

(5) Correlate Stage or Flow Data with Abiotic or Biotic Values

The hydrologic data evaluation becomes of use only when the resource values are associated with a water stage and that stage is in turn related to a flow at a master reference station. For example, the fisheries biologist may dictate that water of 1 foot depth is needed at a certain location. Through the hydrologist's work, that 1 foot is related to a water depth at the reference station. That depth indicates the claimed flow which can be compared with the flow duration curve to obtain some measure of its reasonableness.

Fisheries, Aquatic Organisms, and Riverine Wildlife Component

The determination of the amount of water needed in a channel system to sustain a viable natural fishery, aquatic organisms and riverine wildlife requires analysis of the physical, chemical, and biological components of the aquatic ecosystem. The physical parameters can be measured using the transect method developed and used by Region 4 fisheries biologists. Using this method, satisfactory results can be obtained from low intensity sampling, such as that done for land use planning, as well as from higher intensity sampling being done for water adjudications. Efficiency and versatility have been added to this method through the "General Aquatic Wildlife System" computer program for data storage and manipulation (Collotzi, 1975).

Aquatic Instream Flow Requirements

1. Preinventory

Preinventory work is done to locate critical channel sites within stream reaches as outlined by Herrington and Dunham (1967) and Dunham and Collotzi (1975). Additional sites may be located if habitat needs for specific life stages of the species present are not being adequately described.

2. Field Work

The field crew locates points on streambanks that coincide approximately with critical channel sites marked on maps and/or aerial photos during preinventory. At each critical channel site, five transects are run at 50-foot intervals proceeding upstream from the first point. A photo is taken of the stream at each site for later reference of habitat characteristics and general stream appearance.

Habitat is sampled using cross-channel tape measure lines along which to quantify habitat variables. This is done by tightly stretching a tape measure across and above the water surface at right angles to the direction of streamflow. The tape measure forms the line underneath which habitat features of water and streambottom are identified. It is then a matter of quantitatively stating the habitat in linear measurement figures (i.e., feet of intercept) in appropriate columns of the field form (see Appendix III). Streambank habitat is measured at the cross-channel line's exact streambank point of live water contact.

Discharge is measured and a channel profile recorded. The profile is the channel configuration shown in figure 4 from which hydraulic geometry features are calculated. Average velocity, depths, width, area, and wetted perimeter are key hydraulic variables of each water stage which are tabulated for analysis of habitat retention. It may be necessary to offset upstream or downstream a few feet from the cross section transect to obtain reliable discharge measurements.

Flow velocity may be measured using a current meter. Computations for discharge are completed in the office and the resulting flow is called the index flow. It is the rate of flow in cubic feet per second at the time of habitat survey. The index discharge information is used to compute estimates of flow at additional water stages by solving Manning's formula

$$V = \frac{1.486}{n} \times r^{2/3} \times s^{1/2}$$

for n where V is velocity, r is the hydraulic radius, s is the slope of the water surface, and n is the Manning's coefficient. The n is then used for computing discharge at other water level tracings above and/or below index discharge water level. While it is recognized that n, s, and r vary with stage, this procedure provides an approximate index of flow versus depth that can be correlated with data at the master reference station.

3. Analysis

Upon completion of field inventory, the information is sent to the computer center for storage and manipulation. Output from the

computer includes a printout of a channel profile, a graph showing potential habitat retention at various flows and a table of calculated hydraulic parameters.

The channel profile displays the channel configuration and shows the measured water level and additional levels as desired (figure 4). The graph shows a visual display of tabulated hydraulic parameters retained at the various water levels (figure 5).

The investigator now has the results of the habitat survey and analysis, the index discharge, a channel profile tracing, and a tabulation of hydraulic geometry and discharge at several water levels. The biologist then interprets the relations among and between the several hydraulic variables and habitat retention.

These variables must then be correlated with the chemical and biological components of the system. A discharge level can then be determined which will fulfill life stage requirements for the fish, aquatic organisms, and wildlife species present, at least if it is assumed that water adequate to meet fisheries needs also meets the needs of wildlife and aquatic organisms.

Other Methodologies

There are several other methods which have been developed that can be used when it is not feasible to use the "transect method." These methods were published by Orsborn and Allman, 1976.

If only a rapid records analysis can be made, the Montana method may be used. The Montana method uses a seasonal percentage of average annual flow to protect the aquatic resource. Analysis is based on hydrologic data. It generally reveals the condition of the aquatic habitat to be quite similar on most streams carrying the same portion of the average annual flow. Basically, the 10 percent of the average annual flow is a minimum instantaneous flow to sustain short-term survival habitat for most aquatic life forms. About 30 percent of the average annual flow is considered essential to sustain good survival habitat. Flows of 60 percent or more of the average annual flow provide excellent to outstanding habitat for most aquatic life forms during their primary periods of growth.

Water Quality Component

Water quality relations associated with the dilution of naturally occurring constituents is an important instream consideration. State water quality standards, as well as water use standards, should be considered in the instream flow evaluation process. This can be done by relating changes in flow to any values or standards that are flow related. A single example will be given using the relations between flow and conductivity together with water use standards for irrigation waters.

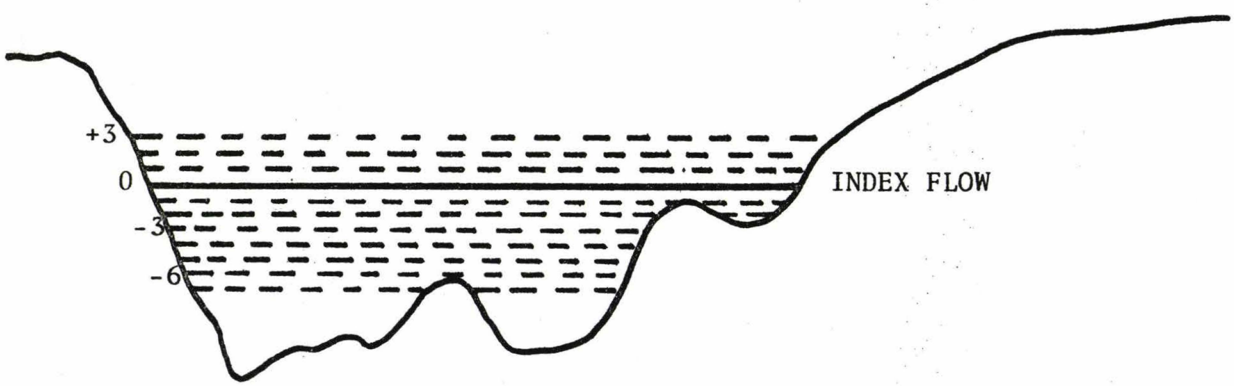


Figure 4. A channel profile showing the measured Index flow level and other selected flow levels.

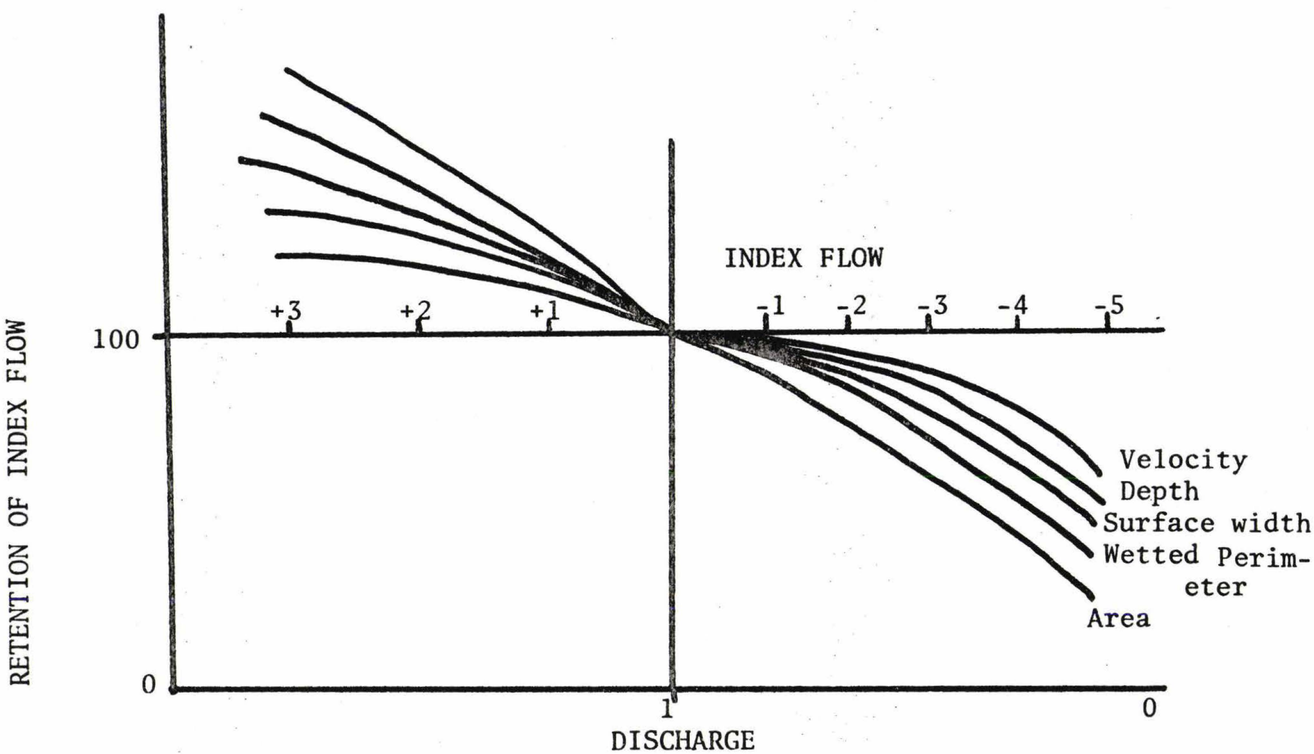


Figure 5. Hydraulic variables at Index and other flow levels.

Conductivity can be related to salinity hazard associated with irrigation water use in the following manner:

Conductivity (Micromhos/cm)	Salinity Hazard
Less than 250	low
250 to 750	medium
750 to 2,250	high
over 2,250	very high

These standards can be used to interpret flow vs. conductivity relations as shown in figure 6. This relation can also be plotted on a log-log scale or on other appropriate scales which transform the data to a straight line.

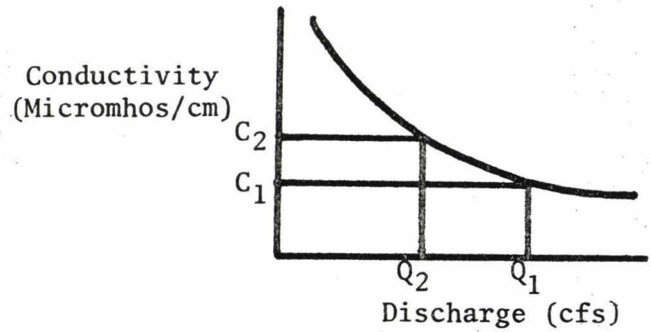


Figure 6. Discharge vs. conductivity.

If existing data are inadequate to develop such relations, a relatively short monitoring period will provide adequate data as long as a wide range of flows can be measured. A rough approximation of the change in quality with a change in flow can then be evaluated.

For demonstration purposes, assume that Q1 is the flow before water is diverted and Q2 is the flow after diversion. Corresponding conductivity values on the curve are C1 and C2. Assume that conductivity of irrigation water leaving the forest must not exceed 1000 micromhos/cm and that at Q1 the conductivity is 300, which is well within the desired value. However, at Q2, the conductivity increased to 1500. Such an increase would not be acceptable.

It must be remembered that these increases in conductivity would not appear immediately below any diversion, but there would be an increase with distance downstream and with channel contact, at least if accretions were insignificant.

The same approach can be used for other flow related parameters such as hardness, calcium, magnesium, bicarbonate, chloride, sulfate, sodium adsorption ratio, and many other variables.

These analyses should be used as only one way to approach instream flow claims and should be correlated with other stream values.

Channel Systems Protection and Maintenance Component

When flow in a channel is partially diverted, there is a change in the capacity of the stream to carry sediment. Yet, below the diversion, sediment is continually washed into the main channel from side tributaries. Over time, this sediment buildup may constrict the main channel and could be both an impact on the aquatic ecosystem and cause increased flood damage and channel erosion.

In order to minimize this impact, the channel should be subjected to the bank-full flow (approximately the 1.5 year recurrence interval flood). This flow is the most important in maintaining channel width as pointed out by Leopold and Woleman (1957). Accordingly, the bank-full discharge should be released for the time period that this level of flow existed under natural conditions.

Navigation Component

Boating and rafting, whether commercial or recreational, are considered in the Navigation Component. These uses include, but are not limited to, sailing, power boating, jet boating, canoeing, kayaking, and rafting.

Navigation is often limited to periods of adequate water supply in the late spring and early summer. It is also confined to the larger streams. Logical considerations in the evaluation process include:

> Identify the present boating and floating activities for all river reaches that are used for this purpose. Special attention should be given to wild and scenic study areas.
>
> Identify the season of use.
>
> Identify the class of use, i.e., powerboat, canoe, rubber raft, and the minimum stage required at the master reference station to support each class of use.
>
> Identify upper stage limits to navigation by various classes of users, at these same reference stations.
>
> Use monthly stage-duration graphs to identify the potential season for each class of use.
>
> Prepare seasonal flow needs for each class of uses for the navigation component.

Recreation and Esthetics Component

Often, recreational and esthetic needs are satisfied by claims for aquatic and riparian habitat, and where applicable, navigation. There are, however, unique situations where specific claims will be necessary for recreation or esthetics.

It is necessary to identify critical channel sites and then apply appropriate methods for evaluating the recreation or scenic values. Specific evaluation criteria for recreation needs will have to be developed on a case by case basis.

In the case of esthetics, photographic records of various flow levels at critical channel sites correlated with master reference stations will allow flow relationships to be associated with various values of visual quality.

Evaluate Seasonal Flow Alternatives (Step 12)

There are two major situations that need to be considered in evaluating instream flows: (1) There are situations where the entire flow is maintained; and (2) situations where the flow regime is altered by partial diversion of flow for one or more reasons at one or more points. It is obvious that a large number of alternatives could be developed for the second situation.

The number of alternatives to be compared must be kept reasonable so the evaluation process will not become unwieldy. Because it is generally necessary to define a feasible and acceptable range of flows seasonally adjusted to needs rather than a single yearly flow value, alternatives with minor differences become insignificant. The major problem then becomes to resolve issues dealing with the quantity and quality of water needed and the timing of use.

After alternatives are developed, an evaluation must be made using the criteria previously established in Step 10 as guidelines for determining viable alternatives. You must decide if water quality standards will be met with each alternative. Will the senior rights of others be honored? Will the National Forest needs be met? Will the decision be socially and economically acceptable? Will lost opportunity costs that would be foregone if instream flows were not maintained be given full consideration?

A subjective decision usually must be made after the pros and cons for each alternative have been tested. Following the decision, the next step is documentation.

Prepare a Schedule of Flows (Step 13)

After an alternative has been selected, it is possible to display the quantity of water needed for each National Forest use. This should be

done on a monthly basis for the master reference station representing each stream reach. The final claim for each month should reflect the quantity of water necessary to meet all of the instream needs. This is not the sum of all functional needs; rather, it is the largest quantity of water required by an individual function which would also satisfy other instream needs. Where several stream reaches are being evaluated along a given stream, make sure claims are correlated.

Prepare Instream Flow Inventory Sheet (Step 14)

After a claim has been established, Form R4-2500-23a should be completed for submission to the Regional Office. This form together with explanatory material for filling out the worksheet has been included in Appendix I. A separate form should be prepared for each stream reach being evaluated.

APPENDIX I
INSTRUCTION GUIDE

Information on the Instream Flow Inventory Data Sheet will be entered into appropriate computer programs. Printouts for use in water adjudications, notifications to States, and for management of the water resource on logical units of land will then be available upon request.

The following instructions should be followed in filling out the worksheet:

Item	Spaces Available	Card 1
1	1	Card Code - 0 = Cancel; 1 = Add; 4 = Change.
2-3	2	State - Use the following State codes: California - 06 Colorado - 08 Idaho - 16 Nevada - 32 Utah - 49 Wyoming - 56
4-5	2	Forest - Forest ADP code number.
6-7	2	Region - Hydrologic unit code as defined by the Water Resources Council.
8-9	2	Subregion - Hydrologic unit code as defined by the Water Resources Council.
10-11	2	Accounting Unit - Hydrologic unit code as defined by the Water Resources Council.
12-13	2	Cataloging Unit - Hydrologic unit code as defined by the Water Resources Council.
14-16	3	Reach No. - Assign a number to each stream reach within 4th order watersheds (cataloging units) that are being evaluated. Do not cross watershed boundaries. Start a new numbering sequence within 4th order watersheds when Forest or State boundaries are crossed.
17-23	7	Purpose - Enter the appropriate number or numbers starting with 1 on the left and going to 7 on the right which indicates the purpose or purposes for which instream flow claims are being made: 1. Fisheries and other aquatic organisms. 2. Recreation (swimming, boating, fishing, etc.). 3. Esthetics. 4. Maintaining riparian vegetation and wildlife habitat. 5. Navigation. 6. Maintaining water quality within acceptable standards. 7. Other - specify with a note on the data sheet.

Item	Spaces Available	Card 1
		Upper Reach Location
24-25	2	Section - Code section number.
26-28	3	Township - Code numerical township designation.
29	1	Township suffix - Code N or S.
30-32	3	Range - Code numerical range designation.
33	1	Range suffix - Code E or W.
34-35	2	Subdivision - To the nearest 40 acres. Use the code number below:

NWNW 4	NENW 3	NWNE 2	NENE 1
SWNW 5	SENW 6	SWNE 7	SENE 8
NWSW 12	NESW 11	NWSE 10	NESE 9
SWSW 13	SESW 14	SWSE 15	SESE 16

		Lower Reach Location
36-37	2	Section - Code section number.
38-40	3	Township - Code numerical township designation.
41	1	Township suffix - Code N or S.
42-44	3	Range - Code numerical range designation.
45	1	Range suffix - Code E or W.
46-47	2	Subdivision - See 34-35 above.

Item	Spaces Available	Card 1
		Reference Point for Instream Claim
48-49	2	Section - Code section number.
50-52	3	Township - Code numerical township designation.
53	1	Township suffix - Code N or S.
54-56	3	Range - Code numerical range designation.
57	1	Range suffix - Code E or W.
58-59	2	Subdivision - See 34-35 above.
60-72	13	Stream Name - Identify stream by name if possible; otherwise, enter "unnamed."
73-80	8	Reservation Date - Specify date reservation was established. Refer only to the stream reach involved. If more than one date or if several ownership patterns are involved, show only the major date and explain in a note.

Item	Spaces Available	Card 2
1	1	Card Code - 2 = Add; 5 = Change.
2-16	15	Follow instructions as given for Card 1. No entries are needed.
17-76	60	Enter the measured or estimated average monthly discharge in cubic feet per second by month. This applies only to the reference point.
77-78	2	Ranger District - Use ADP code number.
79	1	Reach Crosses - Enter the appropriate number for each stream reach: 1. Stream crosses reserved land only. 2. Stream crosses acquired land only. 3. Stream crosses alienated land only. 4. Stream crosses reserved and acquired land. 5. Stream crosses reserved and alienated land. 6. Stream crosses acquired and alienated land.
80	1	Data Base - This entry is used to establish a credibility base for the data. Use one of the three options below: 1. Actual streamflow measurements were made in the field. 2. Streamflow measurements and estimates based on data correlation or watershed parameters. 3. Estimates based on data correlation or watershed parameters.

Item	Spaces Available	Card 3
1	1	Card Code - 3 = Add; 6 = Change.
2-16	15	Follow instructions as given for Card 1. No entries are needed.
17-76	60	Enter the instream flow claim in cubic feet per second by month. This applies only to the reference point.
77-79	3	State Basin Code - Place the number of the area where the use lies as delineated by the State agency responsible for water resources information.

Notes:

A. Description - Provide description of master reference station. An example might be: Water-stage recorder; 7,965 feet elevation; on left bank 0.1 mile downstream from West Fork.

B. Other - Any notes that might be important for clarification.

INSTREAM FLOW INVENTORY
U. S. Forest Service
Region 4

CARD 1

CARD CODE 0 = CANCEL 1 = ADD 4 = CHANGE 1	STATE 2 - 3	FOREST 4 - 5	HYDROLOGIC UNIT CODE REGION 6 - 7	SUB-REGION 8 - 9	ACCT. UNIT 10 - 11	CATALOG UNIT 12 - 13	REACH NO. 14 - 16	PURPOSE 17 - 23
_	_ _	_ _	_ _	_ _	_ _	_ _	_ _ _	_ _ _ _ _ _ _

UPPER REACH LOCATION SECTION 24 - 25	TOWNSHIP 26 - 28	N, S 29	RANGE 30 - 32	E, W 33	SUB. DIV. 34 - 35	LOWER REACH LOCATION SECTION 36 - 37	TOWNSHIP 38 - 40	N, S 41	RANGE 42 - 44	E, W 45	SUB. DIV. 46 - 47
_ _	_ _ • _	_	_ _ • _	_	_ _	_ _	_ _ • _	_	_ _ • _	_	_ _

REFERENCE POINT FOR INSTREAM CLAIM SECTION 48 - 49	TOWNSHIP 50 - 52	N, S 53	RANGE 54 - 56	E, W 57	SUB. DIV. 58 - 59	STREAM NAME 60 - 72	RESERVATION DATE MONTH 73 - 74	DAY 75 - 76	YEAR 77 - 80
_ _	_ _ • _	_	_ _ • _	_	_ _	_ _ _ _ _ _ _ _ _ _ _ _ _	_ _	_ _	_ _ _ _

MONTH	ITEM NO.	CARD 2 AVERAGE MONTHLY DISCHARGE AT REFERENCE POINT (cfs) 2 = ADD 5 = CHANGE 1 —	CARD 3 INSTEAM FLOW CLAIM AT REFERENCE POINT (cfs) 3 = ADD 6 = CHANGE 1 —
JANUARY	17 - 21	_ _ _ _ • _	_ _ _ _ • _
FEBRUARY	22 - 26	_ _ _ _ • _	_ _ _ _ • _
MARCH	27 - 31	_ _ _ _ • _	_ _ _ _ • _
APRIL	32 - 36	_ _ _ _ • _	_ _ _ _ • _
MAY	37 - 41	_ _ _ _ • _	_ _ _ _ • _
JUNE	42 - 46	_ _ _ _ • _	_ _ _ _ • _
JULY	47 - 51	_ _ _ _ • _	_ _ _ _ • _
AUGUST	52 - 56	_ _ _ _ • _	_ _ _ _ • _
SEPTEMBER	57 - 61	_ _ _ _ • _	_ _ _ _ • _
OCTOBER	62 - 66	_ _ _ _ • _	_ _ _ _ • _
NOVEMBER	67 - 71	_ _ _ _ • _	_ _ _ _ • _
DECEMBER	72 - 76	_ _ _ _ • _	_ _ _ _ • _

	RANGER DISTRICT 77 - 78	REACH CROSSES 79	DATA BASE 80	STATE BASIN 77 - 79	
	_ _	_	_	_ _ _	

NOTES:

A. DESCRIPTION ____________________

B. OTHER ____________________

R4 - 2500 - 23A (8/77)

APPENDIX II

MASTER REFERNCE STATION ESTABLISHMENT

Generally, existing and/or discontinued gaging sites of the USGS or other government agencies are good initial master reference stations. If additional gaging stations must be established, a review of the text by Linsley et al., 1958 would be helpful. Chapter 4 contains some good illustrations of alternative staff gage installations.

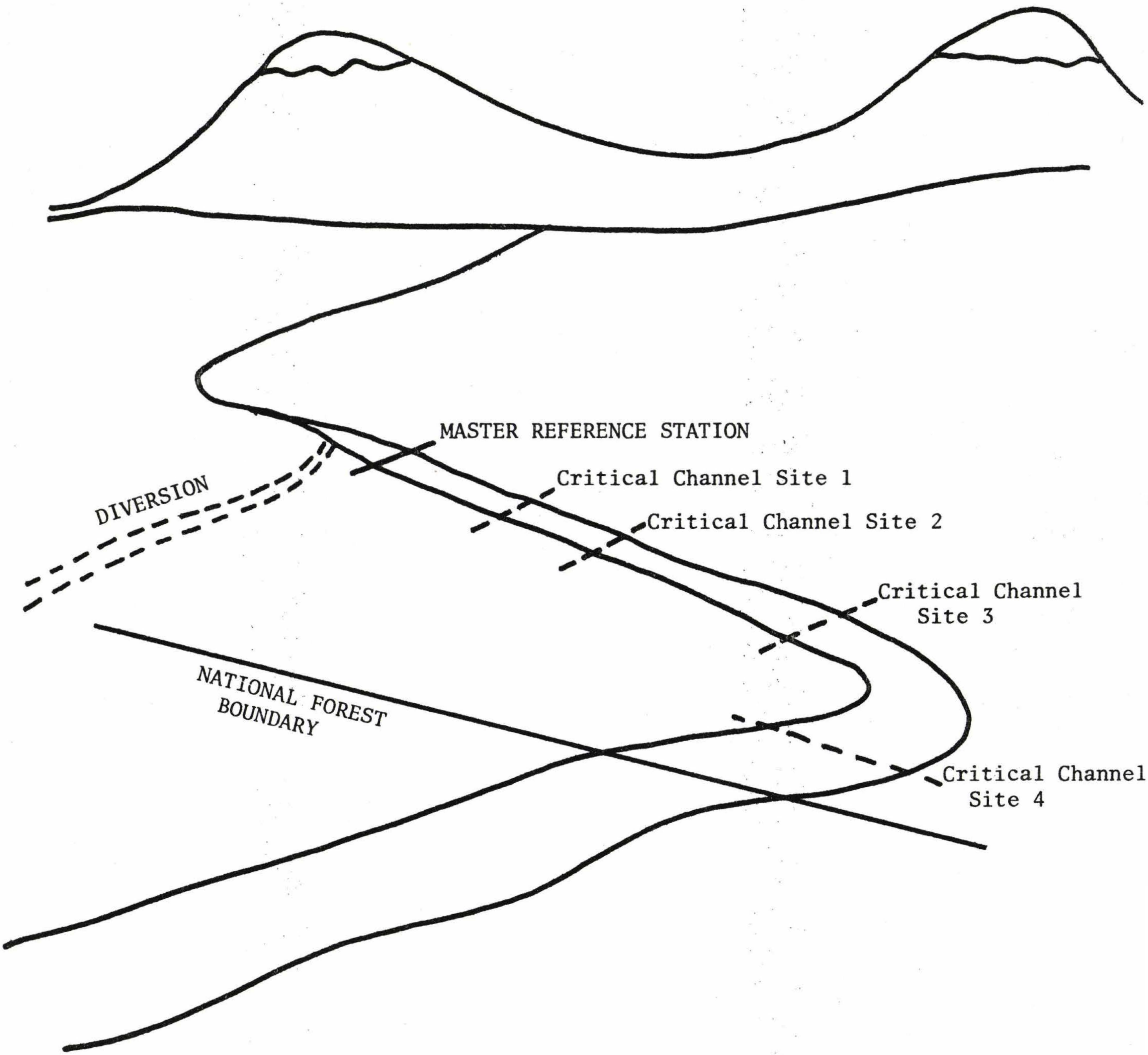
In locating gaging station, representativeness of the reach as well as accessibility are key concerns. Additionally, site characteristics which influence a stable stage-discharge relationship are important to consider. Some of these considerations are discussed by Corbett, 1957.

In general, staff gages should have their datum elevation referenced to a nearby point out of the floodplain area that may be flooded.

Stage measurements can be functionally related to a number of channel values, either at the master reference station or at critical channel sites (see figure below). The following is a partial list of these relationships:

1. Stage vs. flow
2. Stage vs. depth at other locations
3. Stage vs. velocity
4. Stage vs. width
5. Stage vs. surface area of reach
6. Stage vs. wetted perimeter
7. Stage vs. water surface perimeter
8. Stage vs. pool-riffle ratio
9. Stage vs. critical navigation depth
10. Stage vs. visual quality index

Relationship Between Master Reference Point and Critical Channel Sites



APPENDIX III

	WATER SURFACE															
					POOLS											
					1				2				3			
	6	7	8	9	10	11	12	13								
CARD CODE	CHANNEL WIDTH	WATER WIDTH	AVERAGE DEPTH	RIFFLE WIDTH	POOL WIDTH	RATING	LOCATION	FEATURE	POOL WIDTH	RATING	LOCATION	FEATURE	POOL WIDTH	RATING	LOCATION	FEATURE
	3	39	42	45	48	51	52	53	57	60	61	62	66	69	70	71
	xx.x	xx.x	xxx	xx.x	xx.x	x	x	xxxx	xx.x	x	x	xxxx	xx.x	x	x	xxxx
04	--.-	--.-	---	--.-	--.-	-	-	----	--.-	-	-	----	--.-	-	-	----
06	--.-	--.-	---	--.-	--.-	-	-	----	--.-	-	-	----	--.-	-	-	----
08	--.-	--.-	---	--.-	--.-	-	-	----	--.-	-	-	----	--.-	-	-	----
10	--.-	--.-	---	--.-	--.-	-	-	----	--.-	-	-	----	--.-	-	-	----
12	--.-	--.-	---	--.-	--.-	-	-	----	--.-	-	-	----	--.-	-	-	----

Pool Location -
- R right bank
- L left bank
- C center if not bank asso.

Pool Feature -
- 1 boulder
- 2 overhanging bank
- 3 water depth
- 4 veg. or tree roots
- 5 log jam
- 6 beaver dam
- 7 rock outcrop
- 8 other

Type -
- 1 bedrock
- 2 sunken log
- 3 decaying vegetable matter
- 4 other

Bank Measurements
- 1 forested stable
- 2 forested unstable
- 3 brush stable
- 4 brush unstable
- 5 sedge/grass stable
- 6 sedge/grass unstable
- 7 exposed stable
- 8 exposed unstable

Pool rate	Pool length or width	Pool depth	Pool shelter*
1	Greater than ave. stream width	2/3 M or deeper	Abundant 1/
	Greater than ave. stream width	1 M or deeper	Exposed 2/
2	Greater than ave. stream width	2/3 M or deeper	Exposed
	Greater than ave. stream width	less than 2/3 M	Intermediate 3/
	Greater than ave. stream width	less than 2/3 M	Abundant
3	Equal to ave. stream width	less than 2/3 M	Intermediate
	Equal to ave. stream width	less than 2/3 M	Abundant
4	Equal to ave. stream width	shallow 4/	Exposed
	Less than ave. stream width	shallow	Abundant
	Less than ave. stream width	shallow	Intermediate
	Less than ave. stream width	less than 2/3 M	Intermediate
	Less than ave. stream width	2/3 M or deeper	Abundant
5	Less than ave. stream width	shallow	Exposed

* Shelter = logs, stumps, boulders in or overhanging pool. Dense beds of aquatic vegetation or overhanging banks.

1/ Abundant = More than 1/2 perimeter of pool has cover.

2/ Exposed = Exposed (little or no shelter or cover) less than 1/4 of pool perimeter has cover.

3/ Intermediate = 1/4 to 1/2 perimeter of pool has cover.

4/ Shallow = Approximately equal to average stream depth.

		STREAM BOTTOM 15						BANK MEASURE 16	
	14							L. B.	R. B.
CARD CODE	AQUATIC PLANTS	12+ BOULDER	3-12 RUBBLE	1/8-3 GRAVEL	SAND-SILT	TYPE	OTHER	ENVIR. STABILITY	ENVIR. STABILITY
	35	38	41	44	47	50	51	54	55
	xx.x	xx.x	xx.x	xx.x	xx.x	x	xx.x	x	x
5	--.-	--.-	--.-	--.-	--.-	-	--.-	-	-
7	--.-	--.-	--.-	--.-	--.-	-	--.-	-	-
9	--.-	--.-	--.-	--.-	--.-	-	--.-	-	-
11	--.-	--.-	--.-	--.-	--.-	-	--.-	-	-
13	--.-	--.-	--.-	--.-	--.-	-	--.-	-	-

APPENDIX IV

INSTREAM FLOW BOUNDARY CONDITIONS

An instream flow IS	An instream flow is NOT
1. An implied right defined for a particular reservation.	1. A statutory regulation.
2. Applied to reserved lands.	2. Applied to acquired lands.
3. A right to the flow in passing.	3. A right to impound, regulate, or divert at some later time.
4. The quantity of water sufficient to meet defined purposes of the reservation.	4. Excessive use of water resources for purposes outside those defined for the reservation.
5. Associated with an effluent stream which is gaining water from the ground water and is essentially perennial.	5. Associated with an influent stream which is significantly altered by losses to ground water and is essentially intermittent.
6. Valid to maintain riparian vegetation which is symbiotically associated with the aquatic ecosystem.	6. Valid to maintain vegetation which is not associated with the aquatic ecosystem.
7. Valid for maintenance of present dilution characteristics associated with natural water quality.	7. For dilution required to reduce pollution loading associated with activities of man to an acceptable level.
8. Maintenance of channel regime including shape, width, and depositional equilibrium.	8. Flows in excess of needs to maintain channel unless justified for other purposes.